Deep Decarbonization in the U.S. Electricity Sector: Equity Implications and Alternative Policies

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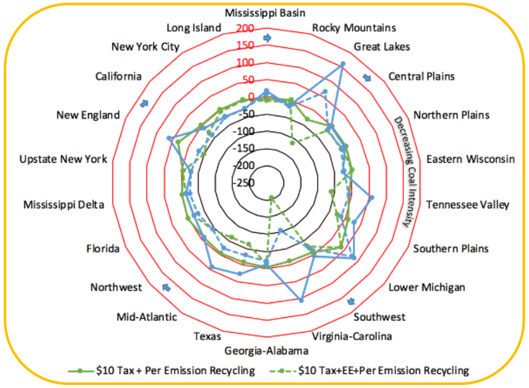
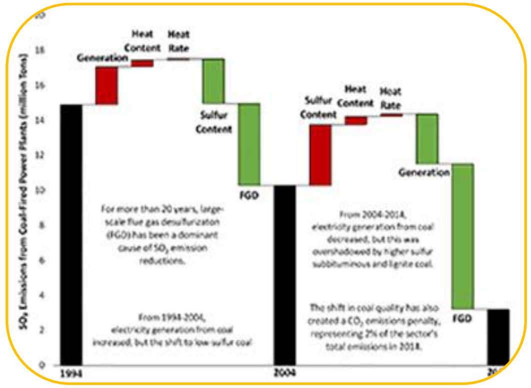
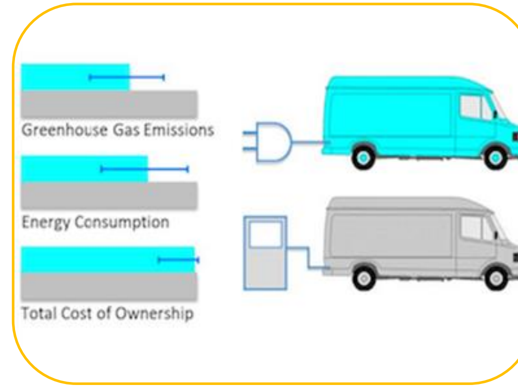
GT Climate and Energy Policy Lab



Winners & Losers ($/capita)

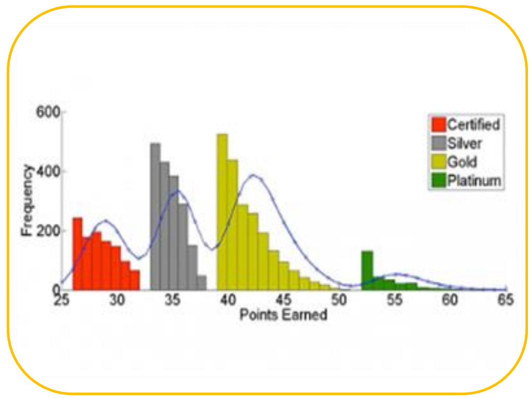


U.S. SO_2 Emissions: Shifting Factors

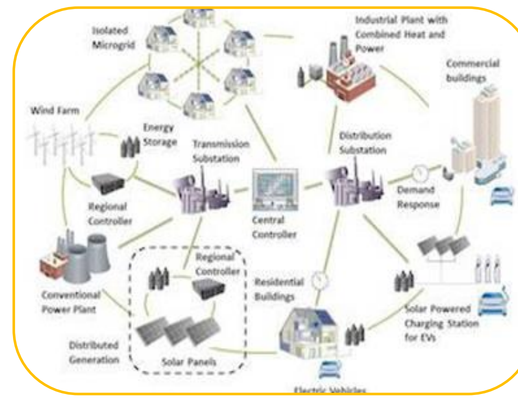


Electric Urban Delivery Trucks

Climate and Energy Laboratory Faculty



Point Distribution for New LEED Construction



The Emergence of Smart-Grid Policies

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MOTIVATION

- The Paris agreement calls for "pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels".

- But few have studied mitigation pathways consistent with such deep decarbonization.
- This paper helps to fill this gap by examining a 25-year transformation of the US electric grid under an array of carbon pricing and energy efficiency policies.

Source: Brown, Marilyn A. and Yufei Li. 2018. "Carbon Pricing and Energy Efficiency: Pathways to Deep Decarbonization of the U.S. Electric Sector," *Energy Efficiency*.

Using Principles of Inertia & Equity, We Create a Cumulative Emissions Goal

(1) We start with a cumulative global CO_2 budget from 2016-2040 consistent with a 1.5 °C limit (Millar, et al., 2017) which is larger than the 2100 estimate because emissions are assumed to be net-negative after 2080.

- ✓Millar global budget for 2016-2040: **939 GT of CO_2**

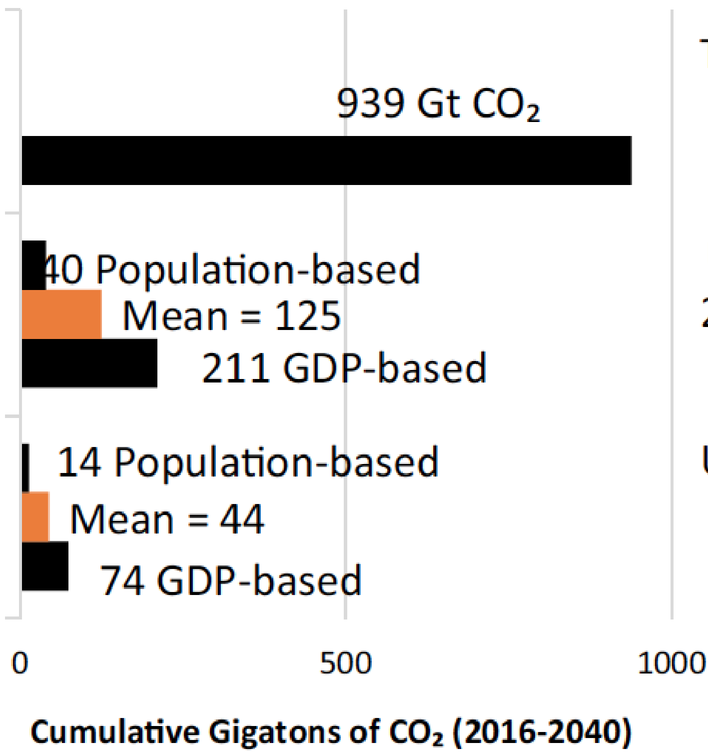
(2) To derive a U.S. share, we use GDP to represent "inertia" and population to represent "equity" (Raupach, et al., 2014)

- ✓211.2 Gt of CO_2 (22.5% of the global target based on GDP)
- ✓40.2 Gt of CO_2 (4.3% of the global target based on population)
- ✓Mean = **125 Gt of CO_2**

(3) Then we allocate 35% of the U.S. cumulative total to its electric sector = **44 Gt of CO_2**

Key sources: Millar, R. J., et al. (2017). Emission budgets and pathways consistent with limiting warming to 1.5°C. Nature Geoscience, 10, 741–747. Raupach, M. R., et al. (2014). Sharing a quota on cumulative carbon emissions. Nature Climate Change, 4(10), 873–879.

Deriving a 1.5°C Budget for the U.S. Electricity Sector



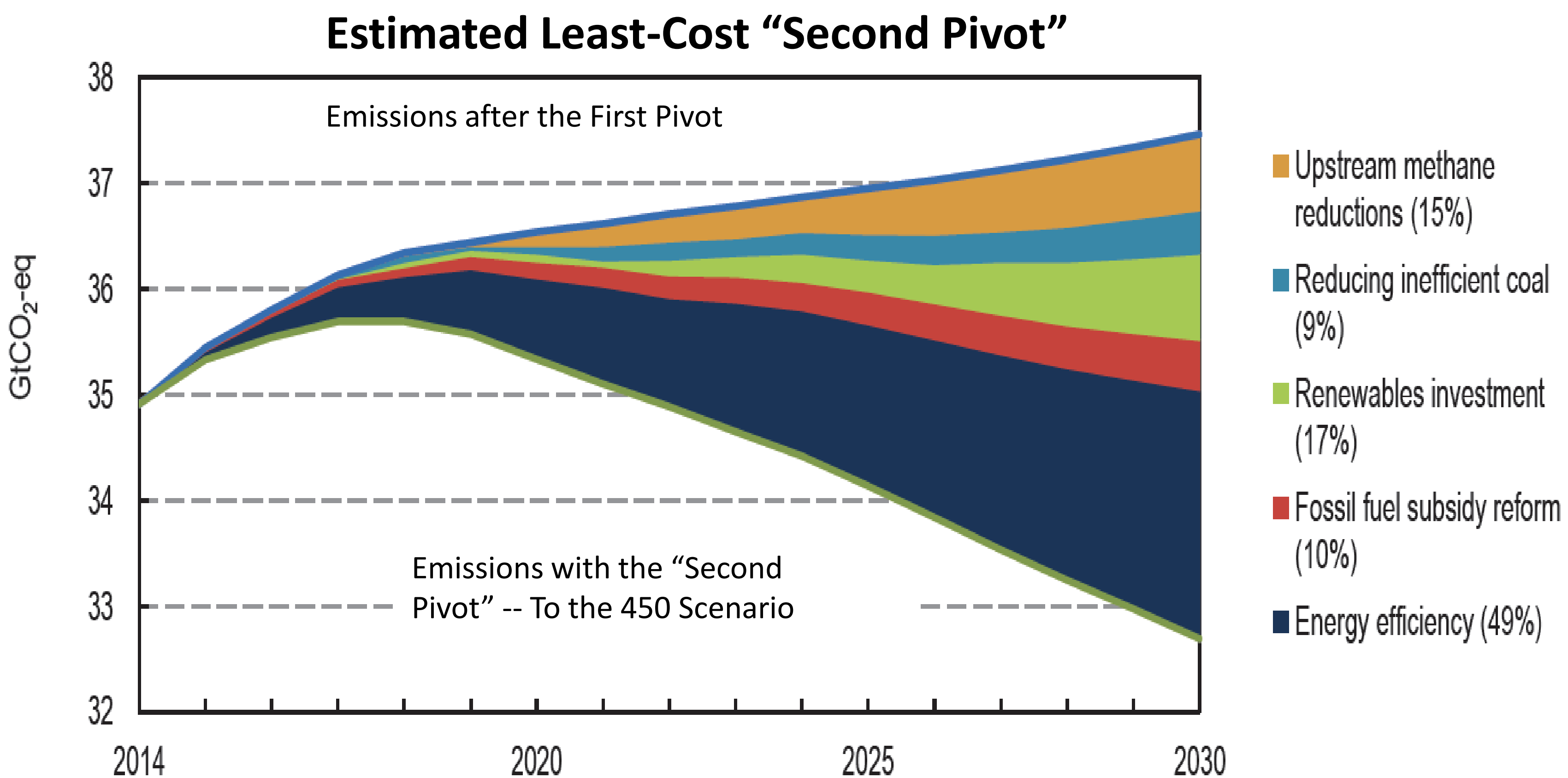
The Global Carbon Budget for 2016-2040, to stay below 1.5°C warming above pre-industrial levels

U.S Carbon Budget (based on 2016-2040 U.S. population and GDP share versus the world)

U.S. Electric Sector Carbon Budget (based on U.S. electric sector carbon share in 2016: 35%)

Thus, a 25-year carbon budget for the U.S. electric sector = **44 Gt CO_2**.

WHAT POLICIES & TECHNLOGIES? Improved Energy Efficiency + Carbon Pricing Will be Critical



IEA (2015) *Energy and Climate Change: A Special Report*

Energy Efficiency has Led to Flat Energy Growth in the U.S.

Flat Growth Base Case

Economic growth offset by efficiencies drives flat load outlook

Compound Average Growth Rate ~0.0%

- Energy efficiency is the fastest growing energy resource in the U.S.
- In today’s U.S. energy workforce of 6.5 million, 2.25 million work in energy efficiency.

Source: NASEO and EFI. 2018. *U.S. Energy and Employment Report.* www.usenergyjobs.org

The "Energy-Efficiency Gap" Persists

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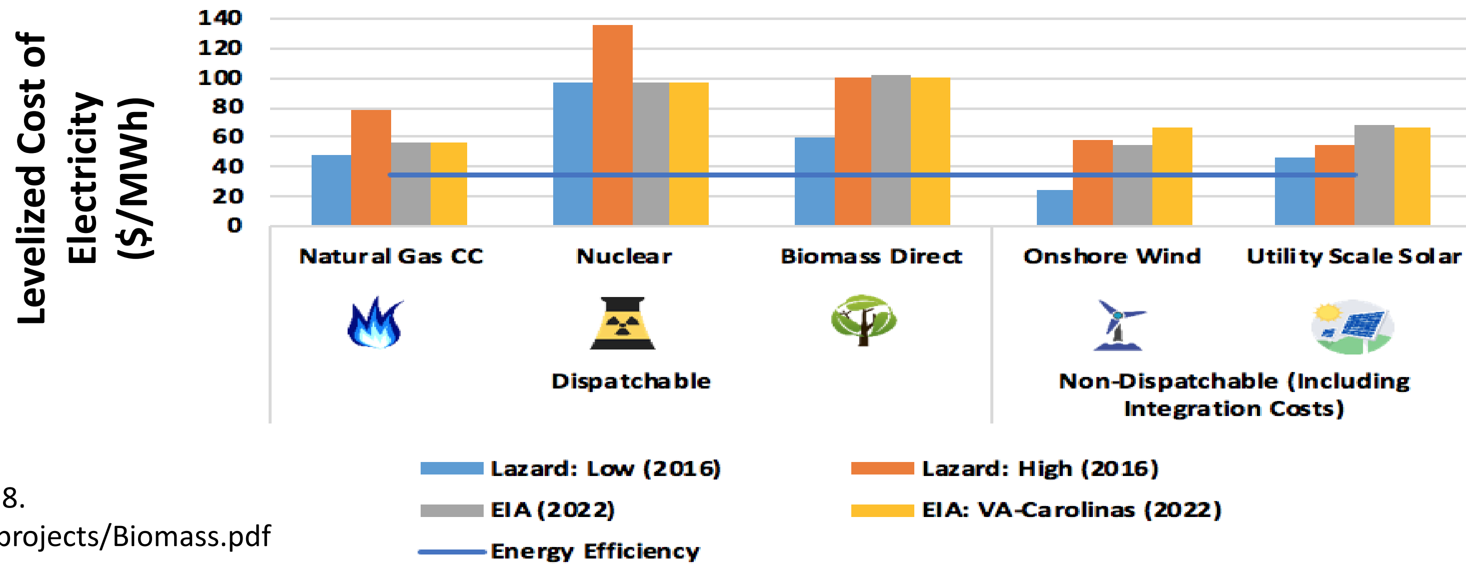
Energy efficiency gap

From Wikipedia, the free encyclopedia

*This article is about the **energy** efficiency gap.*

Energy efficiency gap refers to the improvement potential of energy efficiency or the difference between the cost-minimizing level of energy efficiency and the level of energy efficiency actually realized. It has attracted considerable attention among energy policy analysts, because its existence suggests that society has forgone cost-effective investments in energy efficiency, even though they could significantly reduce energy consumption at low cost. This term was first "coined" by Eric Hirst and Marilyn Brown in a paper entitled "Closing the Efficiency Gap: Barriers to the Efficient Use of Energy" in 1990.[1]

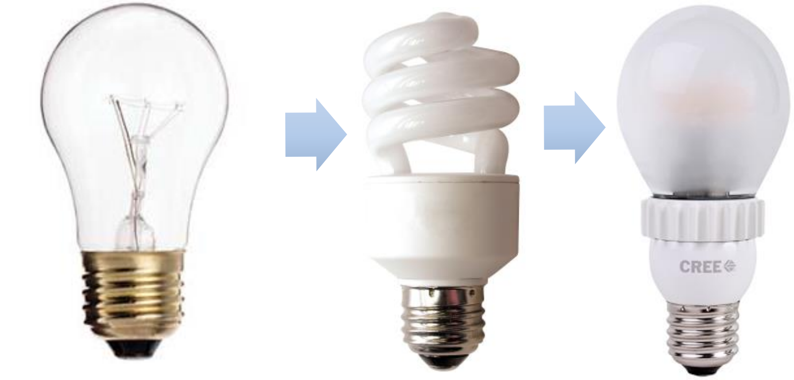


Source: Brown, et al. 2018.
https://cepl.gatech.edu/projects/Biomass.pdf

Energy Efficiency Involves Purchase and Usage Behaviors

- **Energy Efficiency Improvement** – Increasing the services provided per unit of energy consumed.

Avoiding the ubiquitous use of fully lit and conditioned spaces



Watts	60	14	11
Lumens per Watt	14	64	84

Carbon Pricing Also Move Markets: e.g., The "Carbon Dividends Plan"

A Carbon Tax with Revenues Recycled to Households

A Conservative Answer to Climate Change

Enacting a carbon tax would free up private firms to find the most efficient ways to cut emissions.

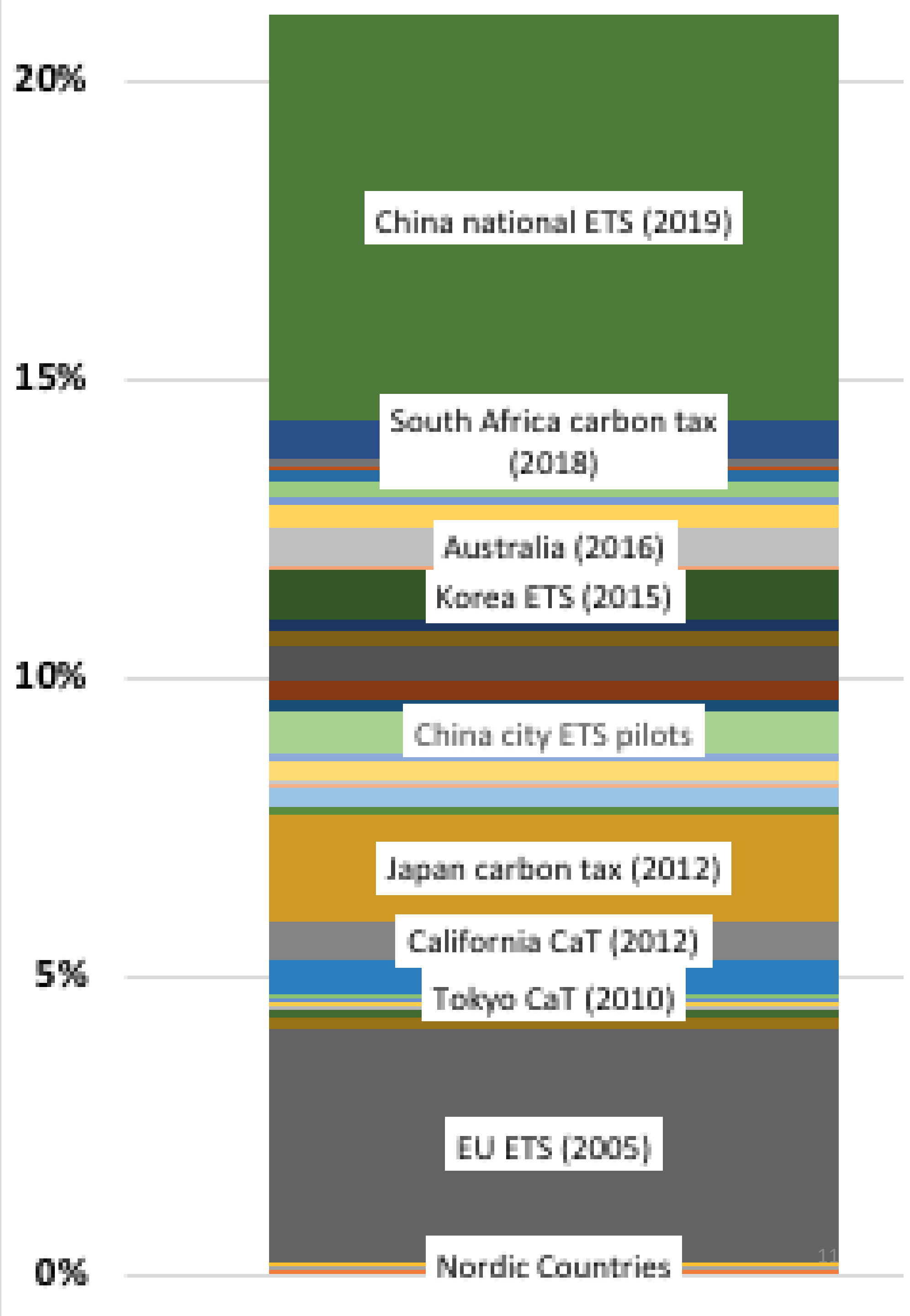
By George P. Shultz and James A. Baker III
Updated Feb. 7, 2017 7:07 p.m. ET

"I really don't know the extent to which it is man-made, and I don't think anybody can tell you with certainty that it's all man-made, … the **risk** is sufficiently strong that **we need an insurance policy** and this is a damn good insurance policy."

James Baker, February, 2017

Redistribute taxes on a per capita basis?
Redistribute per source of CO_2?

Carbon Pricing Schemes Cover 22% of Global CO_2 Emissions



METHODOLOGY: Modeling of Energy Efficiency and Carbon Pricing

- Most energy planning models assume an exogenous reduction of energy demand, associated with a step-curve of costs possessing little granularity.
- These modeling platforms do not compete energy supply and demand resource options
  - ✓ Integrated Planning Model (IPM) used by EPA (2015)
  - ✓ the Haiku model used by Resources for the Future
  - ✓ US-REGEN used by the Electric Power Research Institute
  - ✓ FACETS-ELC used by Wright and Kunudia (2016)
  - ✓ MARket ALlocation (MARKAL) model….

Source: Marilyn A. Brown, Gyungwon Kim, Alexander M. Smith, and Katie Southworth. 2017. “Exploring the Impact of Energy Efficiency as a Carbon Mitigation Strategy in the U.S.” *Energy Policy,* 109: 249-259.

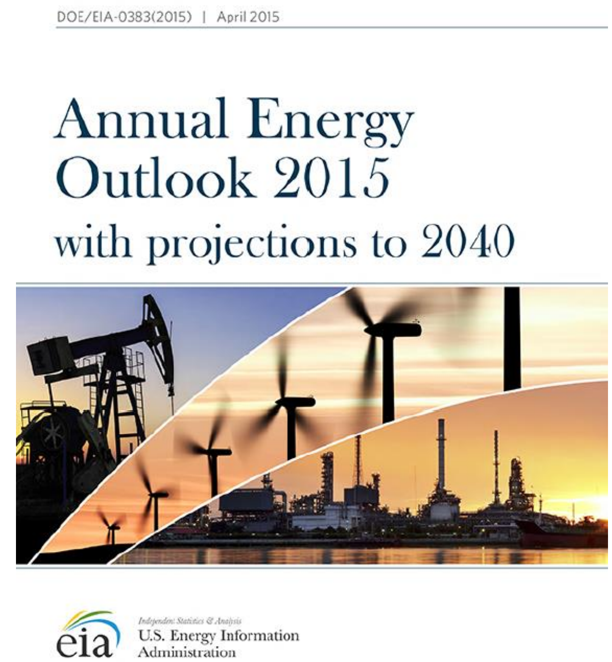
Thus, Nuanced Energy Efficiency Questions are Difficult to Examine

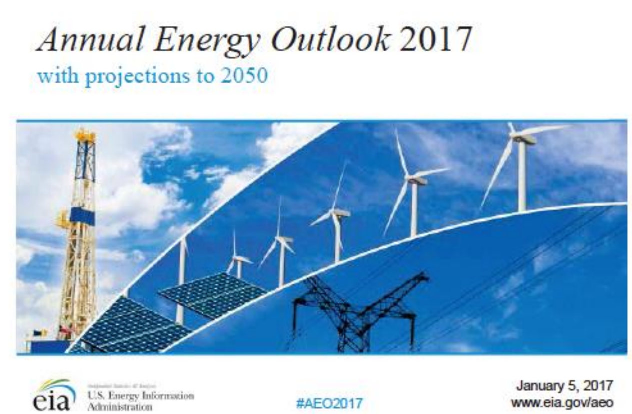
- By misrepresenting energy efficiency as an exogenous resource, possibilities such as the following cannot be explored.
  - ✓ As carbon policies are imposed, EE technologies become more economically attractive & consumers then adopt the technologies in greater numbers.
  - ✓ With increased adoption, high-efficiency demand-side technologies become more economically attractive, leading to increased consumption of EE technologies.
- Models need to allow demand- and supply-side energy resources to compete head-to-head.
- The U.S. National Energy Modeling System does this in an integrated economic-engineering energy model.

Marilyn A. Brown, Gyungwon Kim, Alexander M. Smith, and Katie Southworth. 2017. “Exploring the Impact of Energy Efficiency as a Carbon Mitigation Strategy in the U.S.” *Energy Policy,* 109: 249-259.

The National Energy Modeling System

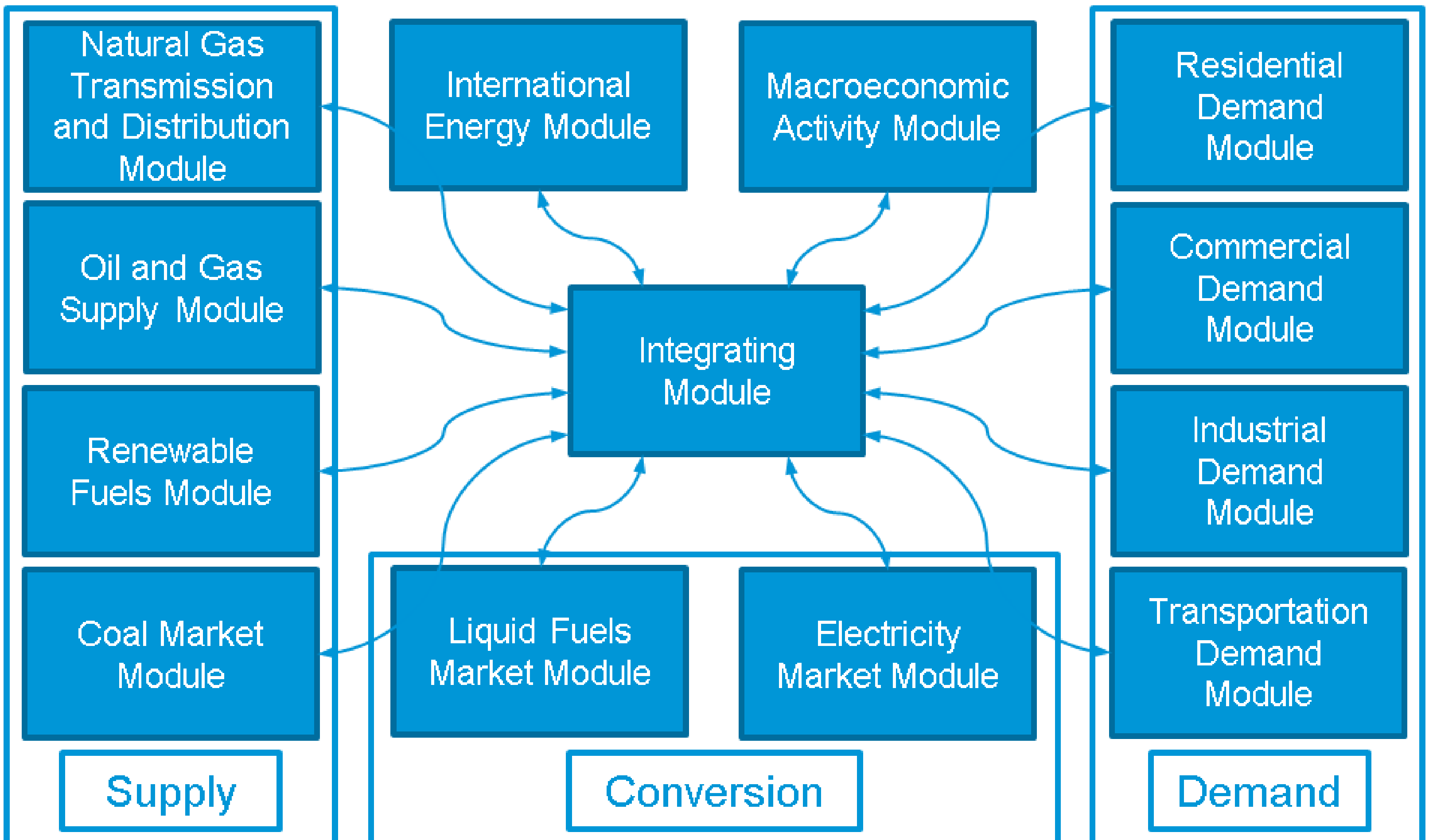
- NEMS: regional energy-economy model of the United States
- Annual projections to 2040/2050:
  - Consumption by sector, fuel type, region
  - Production by fuel
  - Energy imports/exports
  - Prices
  - Technology trends
  - CO_2 emissions
  - Macroeconomic measures and energy market drivers





NEMS Uses a Modular Structure

- A key aspect of the NEMS is its modular structure, which allows for individual modeling methodologies for each energy sector and facilitates model management



Carbon Tax Scenarios

Three levels of an electric power sector tax on CO_2 emissions are modeled, starting from \$10, \$20, and \$40 per metric ton of CO2 (in \$2013) in 2020.

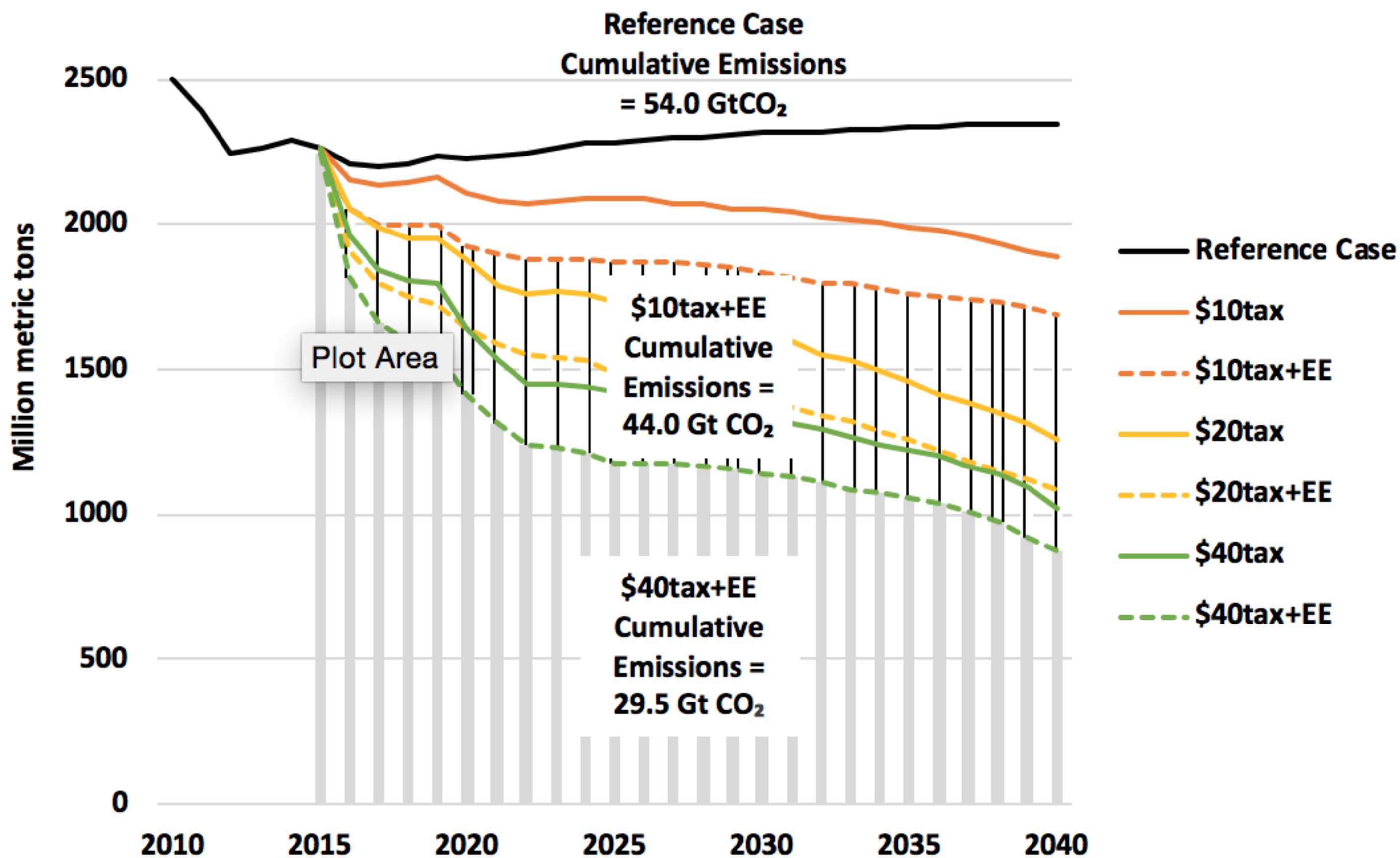
- The \$10 and \$20 taxes are increased 5% annually:
  - ✓the \$10 tax grows to \$16 in 2030 and to \$26 in 2040 and
  - ✓the \$20 tax grows to \$32 in 2030 and to \$53 in 2040.
- The tax starting at \$40 in 2020 increases by only 2% annually reflecting a commitment to rapid impact but a more modest tax incline:
  - ✓It reaches \$49 in 2030 and \$59 in 2040.
- Carbon tax revenues are recycled back to households

Energy Efficiency Policies

Three types of policies are modeled:

- Performance Standards
- Energy Information
- Financial subsidies

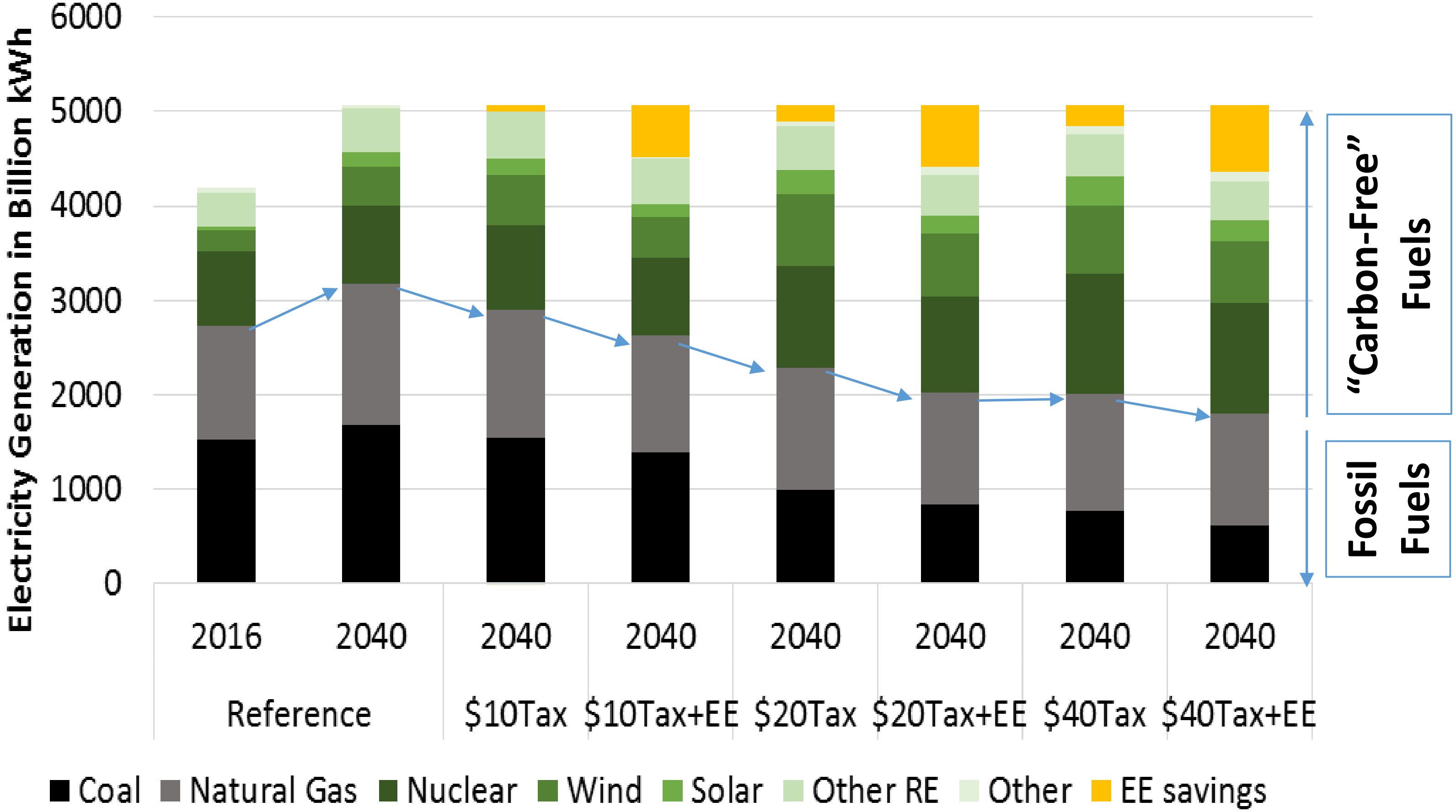
RESULTS: CO_2 Emissions from the U.S. Electric Sector Across Mitigation Scenarios



- Current policies would lead to 54 GT CO_2 in the U.S. electric sector from 2016-2040;
- A $10 tax/ton of CO_2 with strong energy efficiency policies could reduce this to 44 GT CO_2.

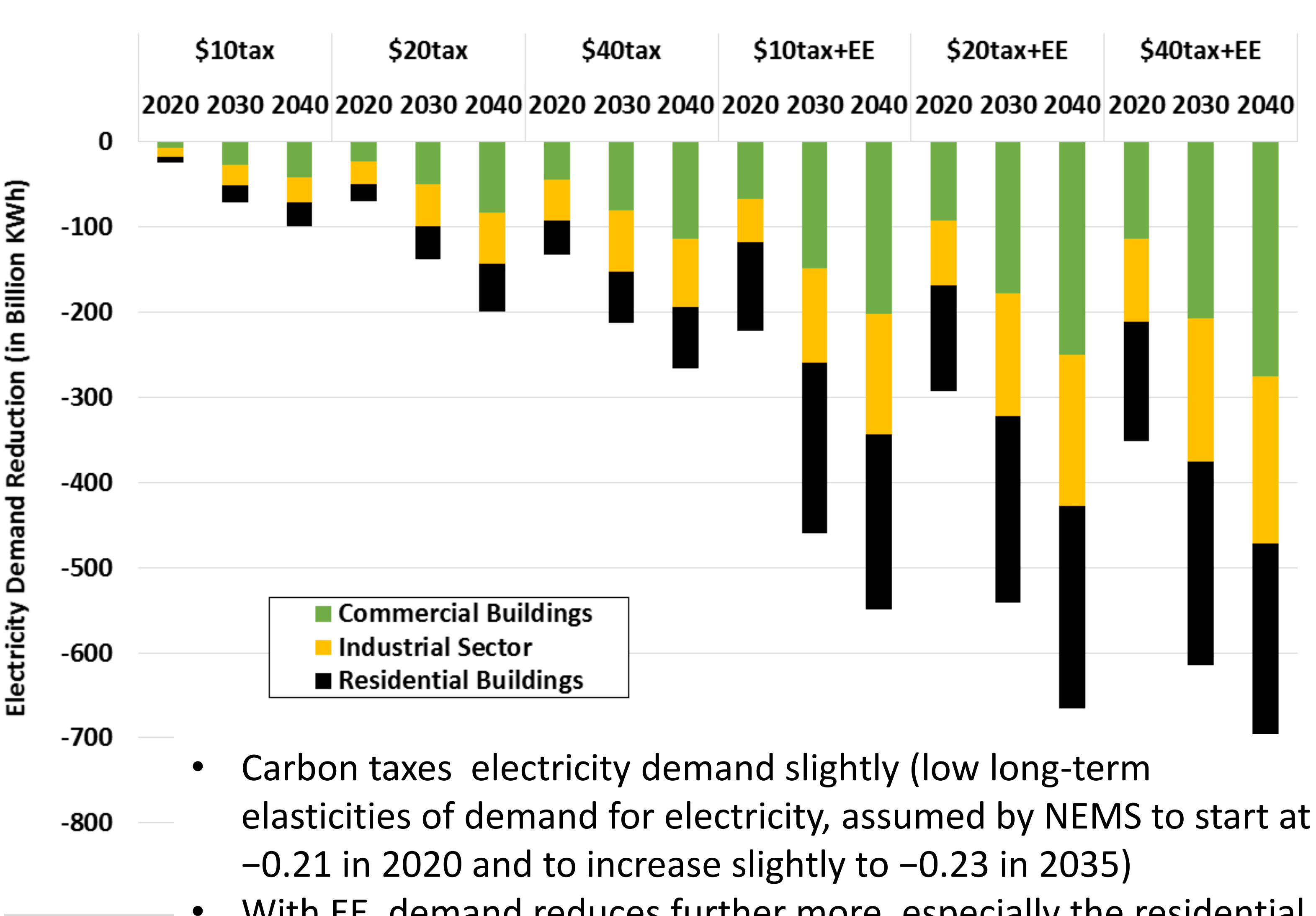
U.S. Electric Sector Fuel Mix

- Each of the six carbon tax scenarios would shrink fossil fuels significantly



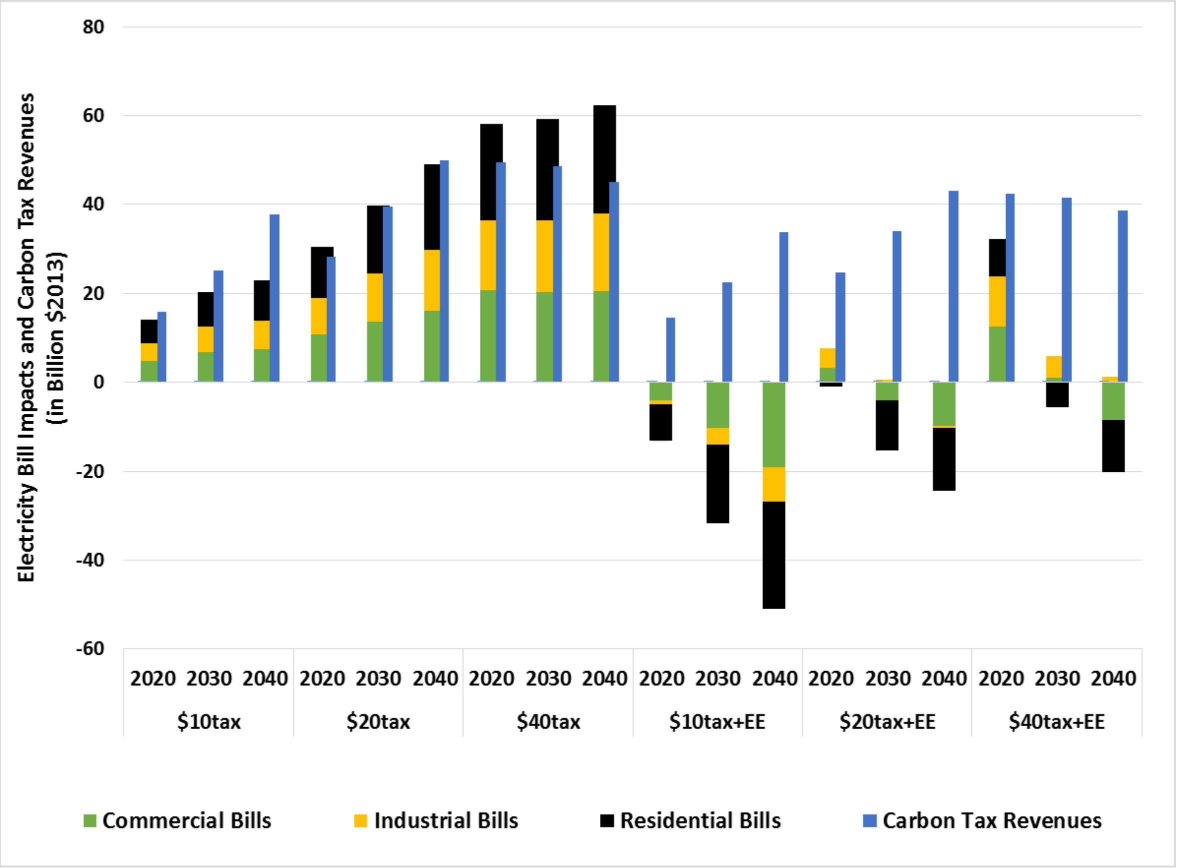
- To offset this decline, nuclear, wind, and solar would grow.
- Scenarios with strong energy-efficiency policies have even less fossil fuel generation.

Electricity Demand Reductions



- Carbon taxes electricity demand slightly (low long-term elasticities of demand for electricity, assumed by NEMS to start at −0.21 in 2020 and to increase slightly to −0.23 in 2035)
- With EE, demand reduces further more, especially the residential sector (black bar above)

Impacts on Electricity Bills and Carbon Tax Revenues

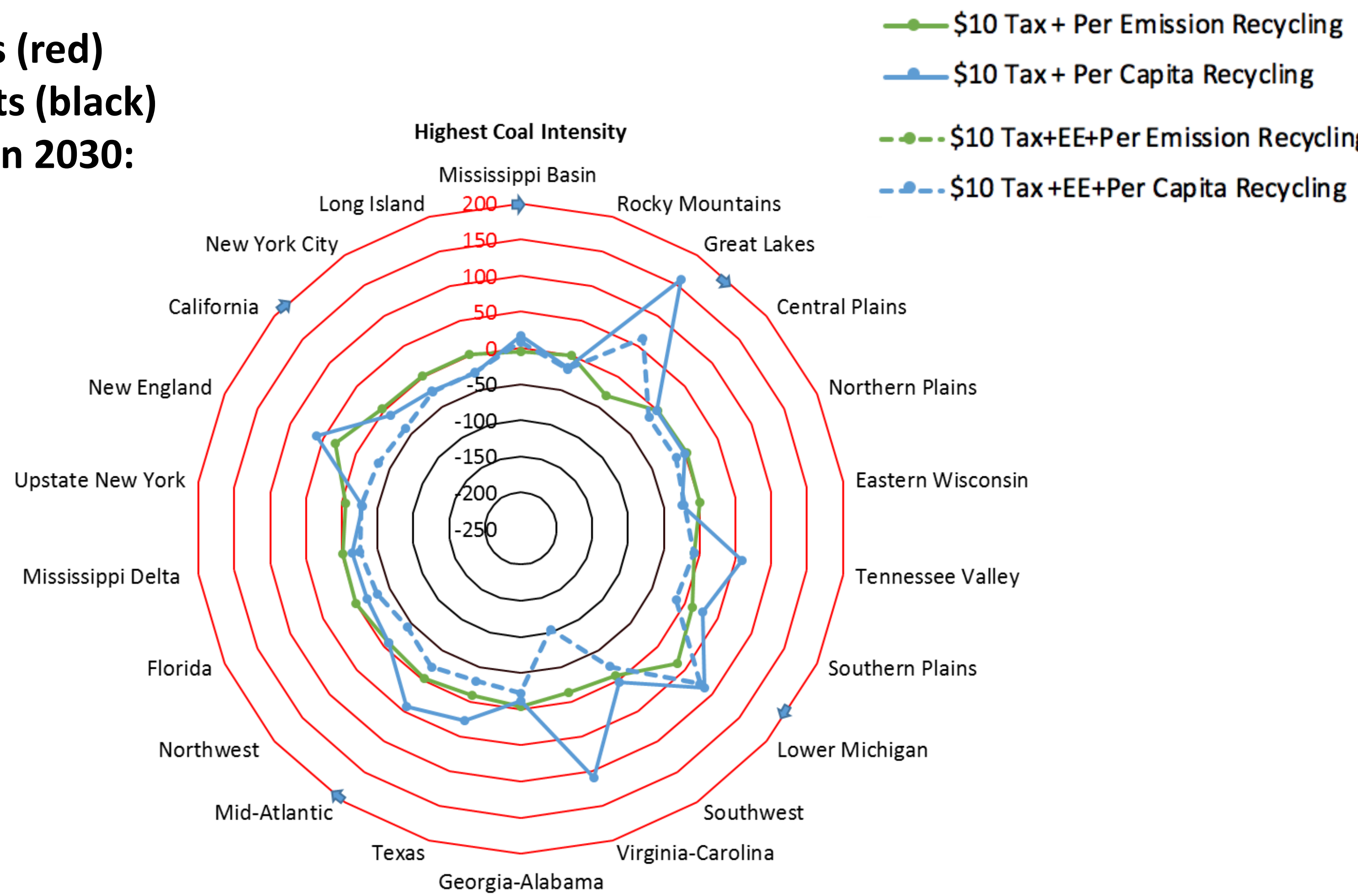


- Recycled carbon tax revenue can compensate for the higher electricity bills and thus reduce the energy burden on consumers

- Adding energy efficiency coupled with carbon tax reveals more uniformly favorable results.

Regional Winners and Losers

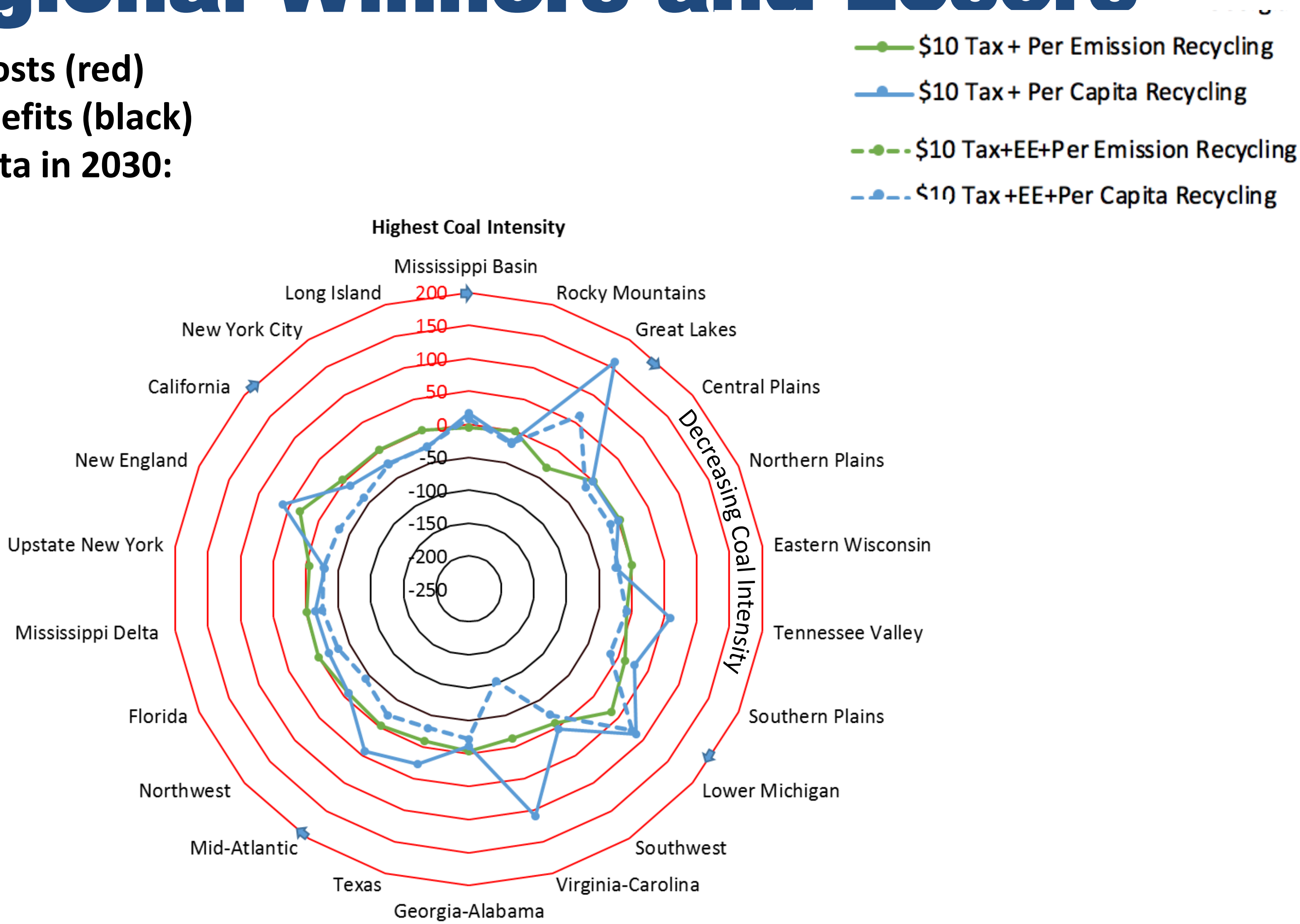
Policy costs (red) and benefits (black) per capita in 2030:



Per capita recycling of tax revenues would result in a transfer of wealth from the South and Central states to the Northeast and Western states.

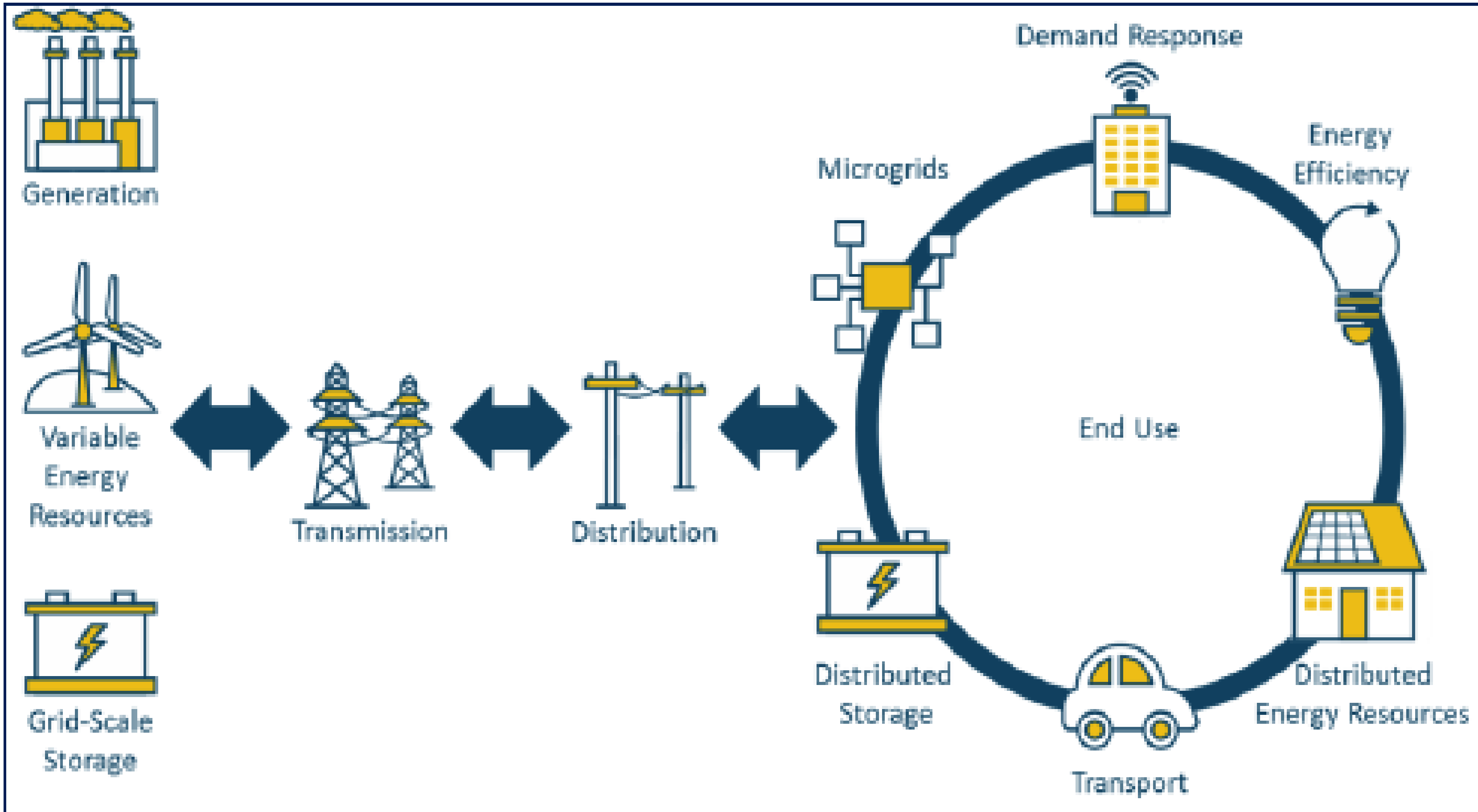
Regional Winners and Losers

Policy costs (red) and benefits (black) per capita in 2030:



"Per emission" recycling of revenues would produce more uniform policy costs across regions.

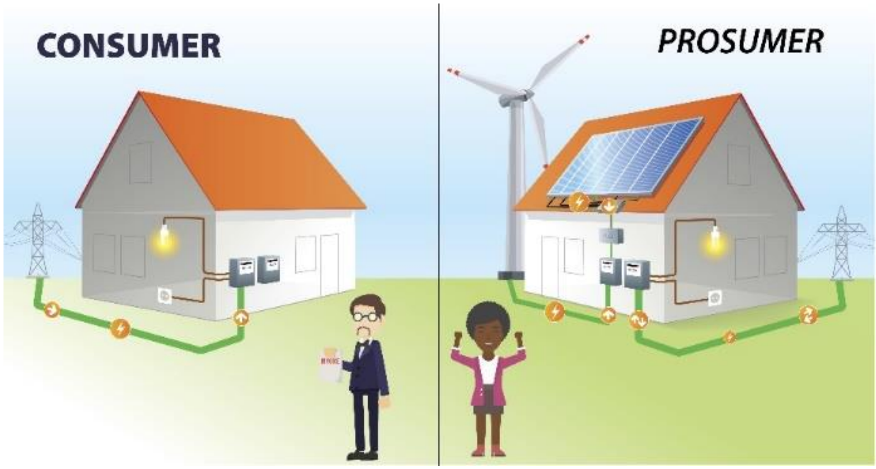
LOOKING AHEAD: The Electricity Supply Chain is Changing



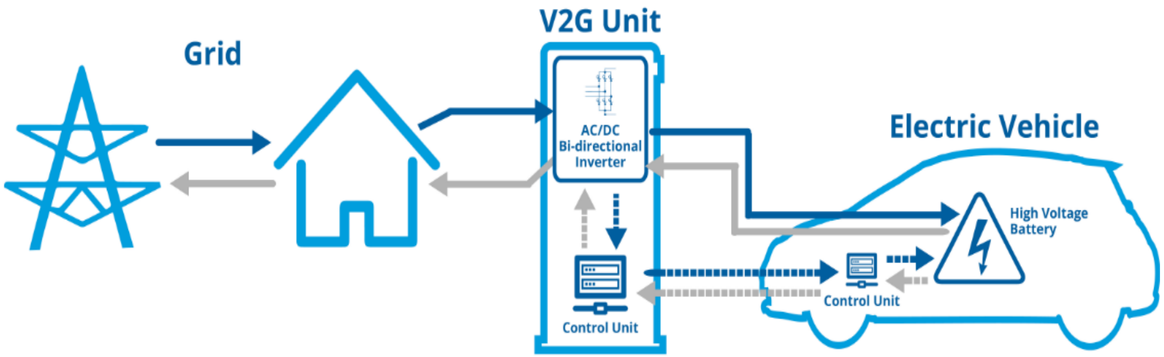
Source: DOE. 2017. Quadrennial Energy Review: Transforming the Nation's Electricity System, Figure S-3

The Creation of "Prosumers" and the "Sharing Economy"

- Consumers are becoming producers as well as consumers – "Prosumers"
  - Facilitated by the falling cost of solar panels
  - Home battery systems are on the move
  - Many more EV models available and a growing charging infrastructure



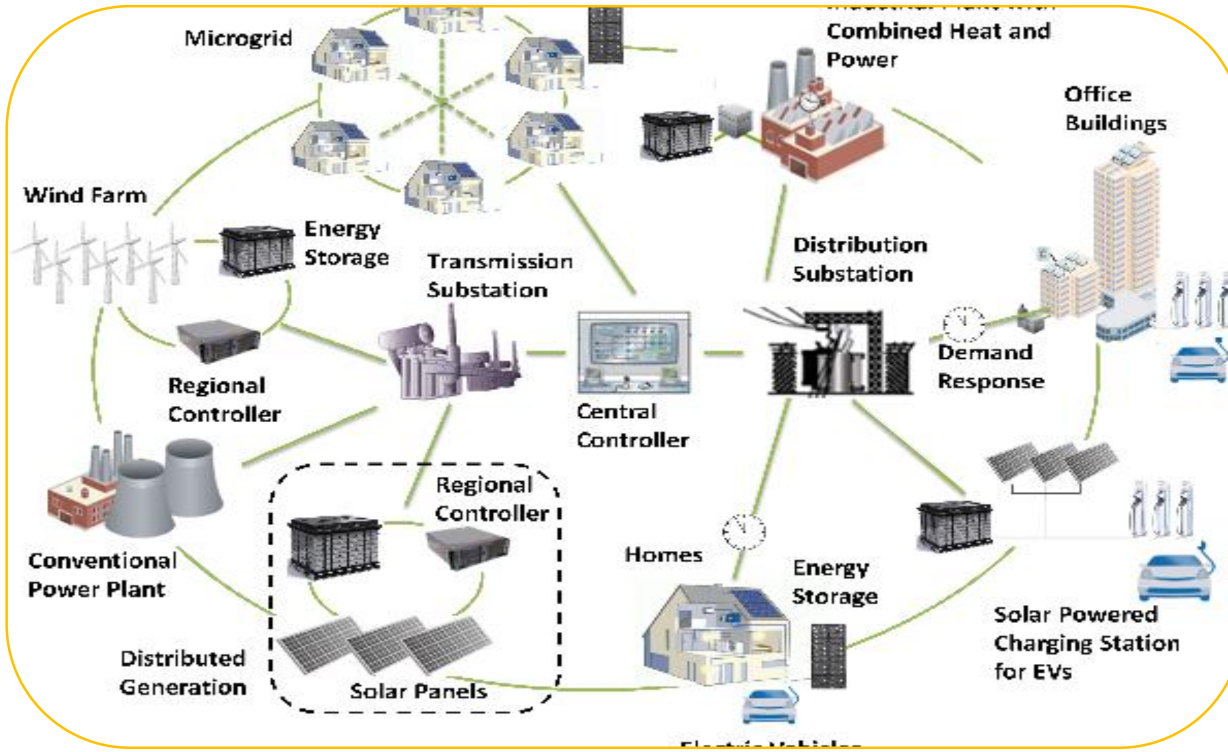
Grid-integrated vehicles could become another form of "prosumerism"



Transportation & Electricity: A Beneficial Merger

More renewable electricity & more electric vehicles: two “complementary” trends:

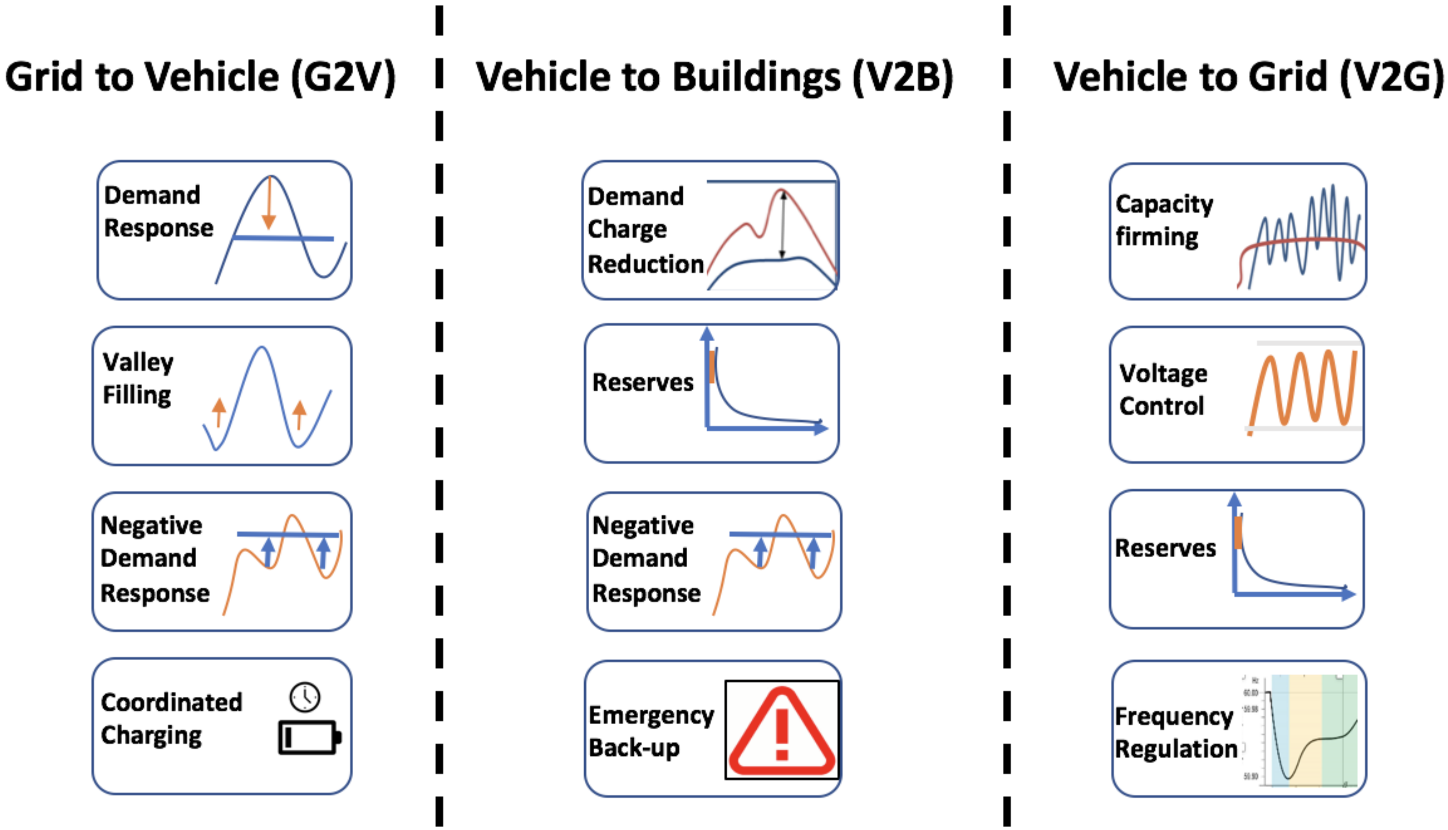
- ✓ With renewables, EVs are even cleaner
- ✓ With EVs, the grid can be better balanced



Brown, Marilyn A., Shan Zhou, and Majid Ahmadi. 2018. "Governance of the Smart Grid: An international review of evolving policy issues and innovations," *Wiley Interdisciplinary Reviews (WIREs): Energy and Environment*.

What Roles Could EVs Play?

- First, they can reduce GHG emissions compared to ICEs.
- But also, they can support the grid.



- How much are these grid services worth?
- What business models can be used to create value?

Conclusions

- Carbon pricing is important, but on its own it could be a costly approach to deep decarbonization because of increased fuel expenses and greater installed power plant capacity costs.
- Strong energy-efficiency policies moderate these costs and in fact can produce cost reductions.
- Approaches to revenue recycling can produce significant transfers of wealth, even if overall they are "revenue neutral."
- In sum, policy design matters!

For More Information

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